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FAST-TRACK PRODUCTS REVIEW: Concrete Pavement Patching Repair Materials

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16. Abstract

Following is a technical research report prepared by the research division on the subject of rigid pavement fast-track patching products and their lab and field testing. This report summarizes a six-year experimental field study conducted with assistance of materials division. Comprehensive lab testing was conducted on various brands of product.

Lab testing included compressive strength, slant shear bond test, and freeze/thaw testing. Field testing included nondestructive pavement testing with a Swiss hammer device. Also, two major experimental demonstration projects were constructed on Interstate 15 in Salt Lake county and in Davis county. Results from the lab and field testing proved that most products performed "excellent". A detail drawing of recommended construction installation is included for reference.

17. Key Words Rapid set concrete, fast track construction, freeze/thaw cycles, PCC pavement, patch.		**18. Distribution Statement** UNLIMITED	
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FAST-TRACK CONCRETE PATCHING REPAIR MATERIALS

Introduction:

Portland Cement Concrete (PCC) pavements in the state of Utah are increasingly in need of repair and rehabilitation. Many of the urban and heavily used sections of our interstate system were constructed with PCC. Although PCC pavements, in general, require little maintenance, the small amount necessary must be performed in a timely manner in order to avoid much more costly repairs in the future.

The demands on our highway system are higher now than ever before and all indications are that these demands will continue to increase. Traditional methods of repairing PCC pavements have called for detours or lane closures for extended periods of time. As traffic volumes over the entire transportation network continue to increase, such detours and closures will become increasingly more difficult to justify in terms of user costs, delays, increased accident rates, etc. Fast-track construction techniques can reduce the time required for repairs to a matter of hours instead of days or even weeks. Often these techniques can be performed during off-peak hours, weekends, or even during night-time maintenance operations, thus limiting impact on the motoring public to a minimum.

In an attempt to meet these needs, the highway construction industry has seen a significant increase in the number of "rapid-set" concrete patching materials now available. The areas of particular concern with these new materials are their long-term durability and their compatibility with other construction materials.

Objectives:

Many of the PCC pavements now in service are experiencing distress in the form of spalling, potholes, rutting, random cracking, and other common rigid pavement distresses. Escalating construction costs make the replacement of these pavement unfeasible. The alternative to replacement is repair and rehabilitation. Major brands of fast-patch concrete products were considered for this pavement study. This report summarizes the efforts from

lab testing conducted during the early stages of research and concludes with longterm field performance evaluations of the products five years after construction. Specific objectives of the testing program and field performance evaluation for the PCC pavement repair materials considered for this study include the following items; method of measurement is parenthetically notated:

T Identify patching materials which are compatible with PCC in the compressive strength and thermal expansion rates. *(Swiss Hammer readings)*

T Evaluate the bonding capacity of each material through slant shear and direct shear testing methods. *(UDOT Test Method)*

T Determine the relative durability of each product through wear and freeze-thaw testing.*(Freeze / Thaw test, ASTM C-666-90)*

T Identify those materials which are best suited for use in the field considering cost, ease of mixing and clean-up, set times, etc. *(Product literature review)*

T Place a representative sample of each material in a field test section to monitor the effects of environmental conditions and traffic loadings. *(Performance field test)*

T Develop a Utah Department of Transportation specification for concrete patching materials based upon evaluation findings. *(Draft standard specification / special provision)*

Performance Evaluations:

A comprehensive evaluation of each patching material was conducted by investigating the following material properties for each product:

Determination of material properties:

- Compressive Strength
- Slant Shear Strength
- Direct Shear Strength
- Thermal Expansion Coefficient
- Freeze/Thaw Resistance
- Resistance to Wear

Description of material handling and uses:

- Working time available for initial set
- Degree and type of surface preparation needed
- Packaging and mixing
- Limitations (time, temperature, weather, etc.)
- Ability to feather-edge
- Curing requirements

Monitoring performance under actual field conditions:

- Pothole repair application
- Thin bonded surface application
- Random crack repair application

Analysis of direct and indirect costs:

- Materials
- Labor
- Equipment
- User Costs

Field Study of Patching Products:

Ten (10) patching products were used on the 1300 South and I-15 Southbound on-ramp to test their strength and durability under actual field conditions. The chronological placement dates (all 1990) for each patch were as follows:

	Product Trade Name	***Date of Placement***
1	Perma Crete	August 12
2	Pyrament (PBCXT)	August 9
3	Euco Speed	August 16
4	EX5B1, Type “III”	September 12
5	Toppit, Magstone	September 21
6	Durapatch Hiway	September 21
7	EX5B1, Type “K”	September 25
8	Sika Set	September 26
9	Burke 928	September 27
10	Dural Guard Modifier E	September 27

The traditional method of saw-cutting 2 to 3 inches beyond the deteriorated concrete then jack hammering out the delaminated or damaged concrete to a sound bonding surface was used for one half of the patches. The remaining patches were prepared by using a super high pressure water demolishing system (30,000 PSI at the nozzle). The hydrodemolishing system uses only 7 gallons of water per minute. The traditional method and hydrodemolishing method of patch preparation are both acceptable methods but the water demolishing appeared, during this patching study, to be much less labor intensive and a less costly system to prepare concrete for patching. The average depth of the repairs was 6".

A literature review of product white sheets was conducted. Following is a brief description of each product with some generic information:

Durapatch Highway is a one component, fiber reinforced rapid set patching material. It is cement based.

A. Non-shrink
B. Freeze/thaw stable
C. Pot life - 15 minutes
D. Material cost per square foot - $ 21.00

EX5B1 is an epoxy modified concrete developed by the Research Unit using Type “K” Cement and a small amount of a Silane based sealer or Type “III” Cement for formed conditions.

A. Non-shrink
B. Freeze/thaw stable
C. Pot life - 2 hours
D. Material cost per square foot - $ 6.50

Pyrament PBCXT is a rapid hardening cementitous material.

A. Non-shrink
B. Freeze/thaw stable
C. Pot life - 90 minutes
D. Material cost per square foot - $ 8.50

Sika Set is a polymer-modified, Portland cement which is rapid hardening.

A. Low-shrink
B. Freeze/thaw stable
C. Pot life - 30 minutes
D. Material cost per square foot - $ 22.25

Euco Speed Magnesium Phosphate is a patching mortar that is also rapid hardening.

A. Low-shrink

B. Freeze/thaw stable
C. Pot life - 12 minutes
D. Material cost per square foot - $ 24.00

Dural guard Modifier-E is a cement concrete mortar additive based on an emulsified epoxy polymer.
A. Low-shrink
B. Freeze/thaw stable
C. Pot life - 30 minutes
D. Material cost per square foot - $ 22.25

Magstone is a magnesium chloride mineral cement (not Portland) and mineral aggregates with a liquid gaging solution.
A. Low-shrink
B. Freeze/thaw stable
C. Pot life - 120 minutes
D. Material cost per square foot - $ 22.25

Burke 928 is a quick setting cementitous compound with mineral aggregate and is a currently approved fiber additive modified concrete.
A. Low-shrink
B. Freeze/thaw stable
C. Pot life - 20 minutes
D Material cost per square foot - $ 24.00

Perma Crete 2 is a combination of tinted Perma-Glaze # 4, 100% solids epoxy formulation and Ottawa natural quartz sand.
A. Low-shrink
B. Freeze/thaw stable
C. Pot life - 15 minutes
D. Material cost per square foot - $ 92.50

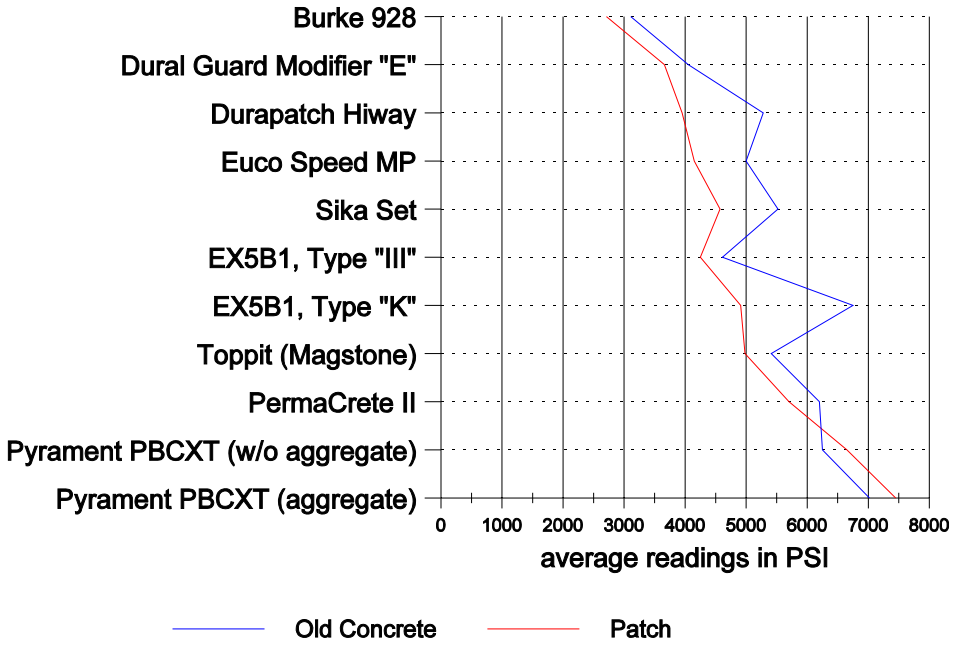
These patches were inspected on January ‘91, September ‘91, August ‘92 and August ‘93, July ‘94, December ‘95, and April ‘96. Final evaluations results show that all patch products performed equally well under severe climate conditions and heavy AADT. *Conclusion for this particular test section was that all products performed “excellent” to “very excellent”.* An additional test section was installed on I-15 near Ogden from Hot Springs to Perry. Results from that field test is presented later in this report with commentary on degradation of patches in transverse and longitudinal joint situations.

Laboratory and Field Testing:

Compatibility of the patching product to the surrounding pavement is important due to the possibility of failure due to thermal expansion. To evaluate this phenomenon the compressive strengths of the patches were measured with a non-destructive testing device known as a “Swiss hammer”. The Swiss hammer is a cylindrical unit with a calibrated resistance meter. When struck it measures the compressive strength at the surface level. Swiss hammer readings were taken below freezing temperature in January 1991. These readings were taken on the patches and on the adjacent concrete.

FIGURE 1

Swiss Hammer Readings (averages)

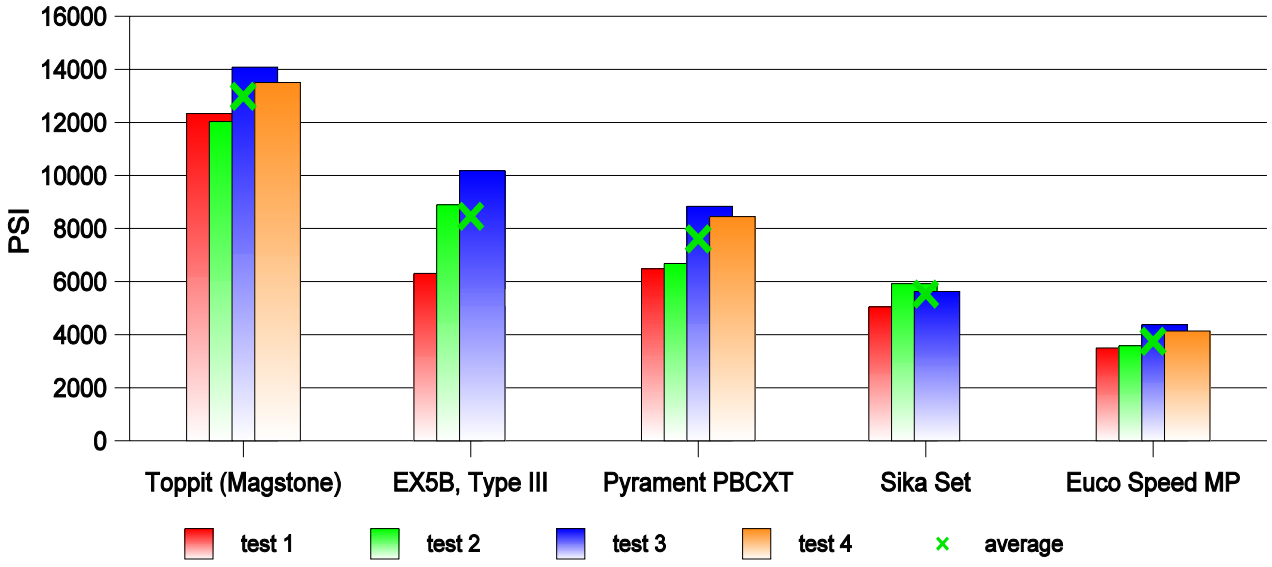


From these Swiss hammer readings we see that generally most products exhibit compatibility with the existing adjacent PCC pavement with the exception of the UDOT EX5B1 Type “K” cement product and possibly the Durapatch Hiway patching compound.

Compressive strengths and slant shear tests were conducted on field samples of EX5B1 Type “K” and “III”, Magstone, Burke 928, Pyrament PBCXT, Euco Speed MP, Sika Set, Fosroc 10-60, Sika Pronto, Regulated Set, Type III Cement, Duracal, Five Star, and Set 45. The compressive strength tests were conducted using cylinders 8 inches long and 4 inches in diameter. The results are summarized below:

TABLE I

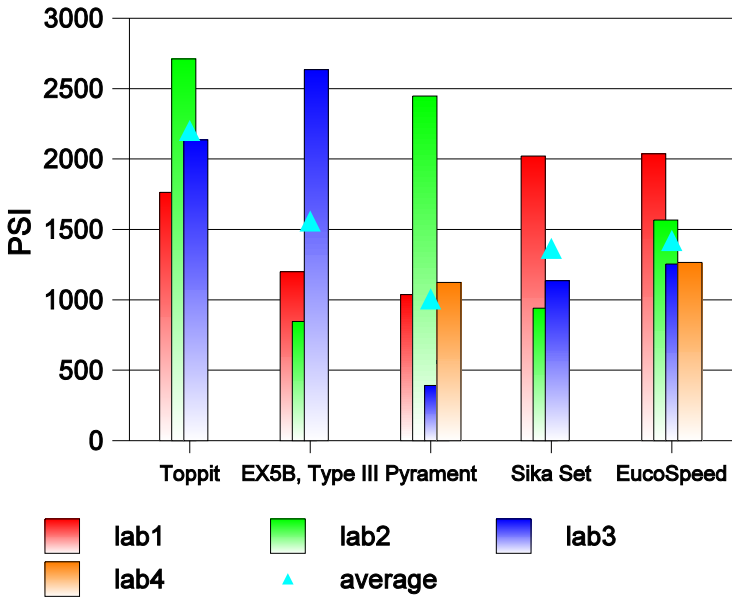
Compressive Strength Tests (Lab Samples)



Slant shear tests were run on field samples of these same products. Ordinary concrete cylinders of the same size used in the compressive tests (8" x 4") were cut on a 45 degree angle to the long axis and a 0.25 inch sample of each product was placed between the two halves and allowed to cure. These cylinders were then tested by the same procedure as the compressive tests. The results of these tests are summarized below:

TABLE II

Slant Shear test (lab results)



Concrete Patching and Repair Products Freeze/Thaw Weight Loss Test:

Utah experiences severe freeze/thaw conditions which has a damaging effect on pavements. A modified ASTM C-109 Freeze/Thaw test was performed for the patching products to determine their freeze/thaw characteristics. Long-term patch durability is directly related to freeze/thaw its compatibility. Following is a step-by-step detail of the modified C-109 test:

I. ***Test specimens:*** Each set of specimens tested shall be cast from a single batch of the specified, by name, patching product. Specimens shall be placed into ASTM, C-109 cube molds. The size is 2" x 2" x 2" cubes. The test cubes shall have a minimum cure time of 10 days and shall be air dried at room temperature for this duration.

II. ***Sample preparation:*** Three test blocks shall be placed upon a plastic mat and cured for 10 days. A minimum of three control blocks (C-109 cubes) will be tested along with the concrete patching material samples in 3%, by weight, Utah road salt solution.

III. ***Freeze/Thaw:*** The control and sample blocks shall be placed in a 10" x 12" x 2" high stainless steel pan with a 3/8" thick plastic mat on the bottom of the pan to prevent any chemical contamination. The sample blocks shall then be approximately ½ to ⅔ submerged in the brine solution during the freeze/thaw test phase. The brine solution shall consist of 3% Utah road salt solution calculated by weight. Temperature cycling will range between 0 degrees Fahrenheit and 60 degrees Fahrenheit on a 3 to 5 hour cycle and will be continuous until 300 freeze/ thaw cycles have been completed. At the end of each 100 freeze/thaw cycles the sample blocks shall be oven dried for six days at 140 degrees Fahrenheit. The dry sample blocks shall then be subjected to 100 more freeze/thaw cycles as described above for a total of 200 freeze/thaw cycles and then oven dried for another six days at 140 degrees Fahrenheit. The sample blocks shall then be subjected to another 100 freeze/thaw cycles for a grand total of 300 freeze/thaw cycles. The sample blocks are to be oven dried for six days at 140 degrees Fahrenheit or until they achieve a constant weight.

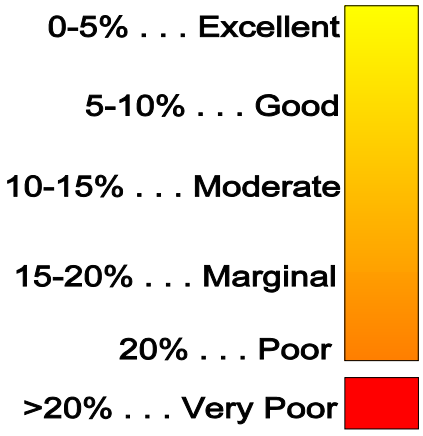
IV. ***Acceptance requirements:*** The oven dry weights of the test samples will be compared to the initial sample weight before the freeze/thaw experience. The samples with a weight loss of 10% or less will be considered for use. Certified test results from a private accredited testing laboratory will suffice for acceptance.

The following products used in the patching projects and laboratory testing were subjected to a freeze/thaw test with a 3% road salt solution and were introduced to 300 freeze/thaw cycles to determine the durability of these products. The percent of weight loss degradation is shown in the chart below. Weight loss parameters of freeze/thaw performance are also shown as color-coded:

Freeze / Thaw Test

	% wt. loss, la	% wt. loss, fie
Durapatch	0.0%	20.0%
PermaCrete	0.0%	--
Gilco	0.0%	--
Burke-Epoxy	0.0%	--
Regulated Se	0.0%	5.0%
LCG90	0.0%	--
EucoSpeed -	0.0%	5.0%
Five Star	0.0%	5.0%
Tremecrete	1.0%	--
CalTrans Pol	4.2%	--
Polyset	5.5%	--
CGM-PG90	6.6%	--
EX5B, Type "	11.8%	14.0%
EX5B, Type "	14.2%	5.0%
EucoSpeed	32.5%	46.0%
PatchRoc "S"	50.2%	--
Pyrament PB	60.4%	15.0%
Pyrament SB	80.0%	--
Duralguard	91.3%	15.0%
Toppit (Magst	100.0%	--
Sika Set	100.0%	--
Rapid Crete	100.0%	--

Weight Loss Performance Range



The durability of the C109 concrete cubes in 3% road salt solution degraded 3.5 times more than the C109 concrete cubes in tap water indicating that the road salt is extremely damaging to this concrete in the laboratory. The average concrete patch product weight loss was 30.3% or 2.5 time more durable than the C109 concrete cubes tested the same 3% road salt solution.

Lab Reporting Conclusions:

This is the final lab report of the repair products installed and tested on 1300 South. This report also includes a number of patching products installed on I-15, Hot Springs to Perry project that were also tested for durability. Results of that pavement test section is discussed in the following section.

This research study included both laboratory and field test results. As noted there were several patching products that performed quite well in the laboratory and field environment. The patching products that performed well had a weight loss of less than 15% in the laboratory results.

Hot Springs to Perry Pavement Test Section:

In an effort to increase the life of damaged rigid pavements, the Utah Department of Transportation (UDOT) Research & Development division conducted a field research project in cooperation with FHWA on concrete pavement rehabilitation using fast-patch products for spall repair at transverse and longitudinal joints. Twelve different fast-set concrete patching products were selected for comparison. The testing program comprised of both laboratory and field performance tests. Laboratory testing included bond (slant/shear) test and freeze/thaw weight loss test. Field performance testing included evaluation of patch performance and joint performance.

Field Testing:

Four concrete fast patch products were originally scheduled to be tested in the Spring of 1991 on the mainline of I-15 just north of Ogden, Utah. A short time after placement, one product failed and was replaced by a fifth product. While this project was in progress, the Research Division received a request to use similar patching products to repair the on- and off-ramps at the Willard Bay Interchange. The original four products and several new products were placed on the ramps and have been evaluated along with the patching materials that were placed on the mainline of I-15. In this report the evaluation of the patching materials for spall repair on the ramps and mainline have been addressed separately. The original project will be

referred to as “mainline” and the second will be called the “ramp” project. The mainline consists mostly of repairs to localized failures at joint edges of the concrete slabs. The ramp project consisted of mainly of repairs to large longitudinal slab cracks.

The main objective of this study is to inform the interested parties on how the different patching materials are performing after six years of field performance and critical evaluation. The characteristics of the patches that were used for this performance evaluation were: delamination (debonding from pavement), spalling (when pieces of the patch break away from the patch or pavement), and cracking.

There were a few patches that exhibited slight surface raveling, but not to the extent that it affected the performance of these repairs. If the severity of the surface raveling increases to the point that it may affect the pavement performance, then this increased raveling will be addressed at that time.

Evaluation of Mainline Patches

The following patching products were installed on the I-15 mainline project:

- ì Sikaset a product of Sika Corporation
- í Patchroc 10-60 a product of Celtite Inc.
- î Toppit a product of Maya Magstone Inc.
- ï Ex5b a UDOT Research experimental product.
- ð Burke 928 a product of Burke Concrete Accessories

Within three months the Toppit had degraded to a point of failure and had to be replaced. Burke 928 replaced Toppit.

The performance of each of these products was based on field investigations through detailed and thorough comparative evaluation. Soundness tests were made and distress history was taken at each interim site visit.

Patch spalling for the products evaluated over the five year history are summarized in the table below. Table III presents the percent degradation of the patch area when compared to the average spalling for the many sections of patching performed on the pavement. In general, the products performed "excellent" with regard to prevention of spalling, as anticipated from the lab test results discussed previously.

Table III : SPALL DEGRADATION OF PATCH
Mainline Section (Nov 1996)

PRODUCT NAME	*AREA(SF)*	*SPALL(SF)*	*% DEGRADED*
CELLROC 10-60	114	0.19	0.17
EX5B	92	0.74	0.80
BURKE 928	112	1.60	1.43
SIKASET	155	2.49	1.61
TOPPIT	FAILED		
TOTALS	47I3	5.02	1.06

The cracking observed in all of the patching products consisted almost entirely of hairline cracks. Hairline cracks are small enough not to affect the performance nor be affected by weathering. The few significant cracks that were observed in these patches were all associated with points of failure (spalls and delams).

Comparison of Preparation Methods

Two different procedures were used to prepare the concrete pavement for patching repairs. The first procedure prepares the damaged areas by sawcutting, breaking out the deteriorated material using a jackhammer and then sandblast to prepare the patch. The second procedure is called hydrodemolishing and uses a water blast under high pressure (30,000 PSI) to remove deteriorated concrete and prepares it for patching. The claimed benefits using hydrodemolishing are a reduction of microfractures caused by the hammer impact in the traditional method. Also, it allows more surface area for the patching material to bond against.

This evaluation evidences that the hydrodemolishing procedure is almost three times as effective as the saw cut and jackhammer preparation method in patch performance. See Table IV below:

TABLE IV : COMPARISON OF THE TWO METHODS OF PREPARATION

Mainline Section (Nov. 1996)

PRODUCT NAME	PERCENT DEGRADATION	
	TRADITIONAL	*HYDRODEMOLISH*
BURKE 928	**0.40**	**0**
EX5B	**1.00**	**0.30**
CELLROC 10-60	**3.50**	**0.30**
SIKASET	**2.00**	**1.50**
TOPPIT*	**FAILED**	
TOTALS	**1.80**	**0.70**

Evaluation of Ramp Patches

The following products were installed on the Willard Bay Ramp Project:

1. Sika Pronto
2. Cellroc 10-60
3. EX5bB
4. Five Star
5. Duracal
6. Set 45
7. Regulated Set
8. MC 64
9. Type II Low Alkali Cement
10. Burke 928
11. Toppit

The Toppit failed after three months and was replaced by a second Toppit installation. The products used in the ramp project were evaluated using the same parameters as listed in the mainline project. The results are listed in Table V on the next page:

Table V: DEGRADATION OF LONGITUDINAL JOINT PATCH
Ramp Section (Nov 1996)

PRODUCT	*AREA(SF)*	*FAILURE(SF)*	*% DEGRADED*
MC 64	**13**	**0**	**0**
BURKE 928	**27**	**0.03**	**0.11**
TYPE II LOW ALK.	**108**	**1.16**	**1.07**
FIVE STAR	**92**	**2.26**	**2.46**
DURACAL	**198**	**6.22**	**3.14**
CELLROC 10-60	**73**	**2.52**	**3.45**
EX5B	**312**	**14.42**	**4.62**
REG-SET	**239**	**10.61**	**4.44**
SET 45	**16**	**1.83**	**11.44**
SIKA PRONTO	**110**	**24.51**	**22.28**
AVERAGE	**1,188**	**63.56**	**5.35**

Conclusions:

I. Mainline Patch Repair: These patches were primarily rectangular and were located at the transverse, sawed and sealed joint. Note on Table III that excepting the Toppit that failed within three months after installation. The other fast patch materials performed at a 1.06% degradation rate in the five years of evaluation. A 99% success rate on spall repairs over a five year period indicates that the repairs have a longer successful life than the existing pavement. An 0.2% per year spall degradation theoretically will exhibit 90% success over 50 years! Mainline patch repair has been and is a viable scheme to enhance and prolong all concrete pavement when there is deemed a need.

II. Patch Preparation:

A. Traditional patch preparation and repair includes perimeter sawcuts, jackhammer 3 to 5 inches deep, clean with air blast, wet clean the surface to receive the concrete repair material per manufacturers specification. This repair process exhibited a 98.2% success rate over a five year period.

B. Hydroblasting includes a high pressure demolishing (30,000 PSI) of the spalled (degraded) areas 3 to 5 inches deep leaving a rough surface finish that creates more surface area for the patching material to adhere to, thus, possibly creating a better preparation method, all things being equal, and a higher success rate. This type of repair process exhibited a 99.3% success rate over a five year period.

Both techniques proved satisfactory, however by arithmetic the hydrodemolish preparation was almost three times as effective.

III. Degraded Ramp Repairs: The sawcut-and-jackhammer repair method was used on all the ramp repairs. Be aware that the degraded concrete on these ramps include not only transverse joint damage but longitudinal concrete cracking caused by to few relief cuts for the width of these ramps. As noted on Table V the average success rate was 94.65% over a five year period or 1% per year, five times less of a success than the main line repairs but these ramp repairs at a minimal installation cost extended a near failing pavement by at least 10 years of life. Cost to install these patching products vary only in the price of the material with all other costs being about equal.

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